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REPORT ON THE GROUNDWATER AT
THE PORT GRANBY RADIOACTIVE WASTE
MANAGEMENT SITE FROM 1981 TO 1983

by

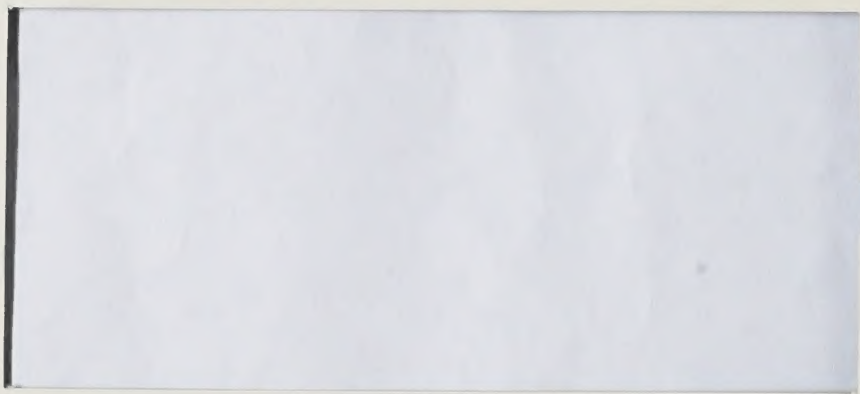
R.F. Platford, J.A. FitzGerald, A.G. Bobba
and S.R. Joshi

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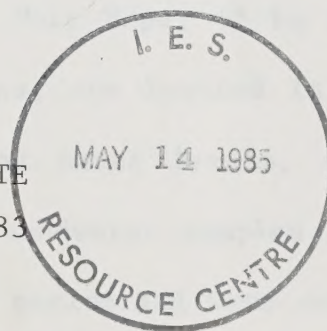


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INTRODUCTION

This report summarizes the measurements which we have made during 1981-83 at the Port Granby waste management site. A previous paper (Durham and Joshi, 1980) deals with measurements at the site until 1980, and a report by James F. MacLaren Ltd. (1977) gives a comprehensive history of the site. The nearshore geology is obtainable from a report by Rukavina (1981), and for comparison purposes the levels of radioactivity in Lake Ontario can be obtained from a report by Durham et al. (1981).

The Port Granby site is operated by Eldorado Resources Limited, and was used from 1955 to 1979 for the disposal of radium waste from their uranium refinery located in Port Hope, 13 km to the east. A series of piezometers, or standpipes, are located in a row along the shore for the purpose of measuring water levels, and to provide reproducible locations for taking groundwater samples. Such samples have been collected over a three-year period and were analyzed for radium-226 and uranium.

URANIUM PROCESSING

The end product of the uranium refining process is UF_6 which can be enriched in the fissile isotope, U^{235} , by means of the gaseous

diffusion process. Uranium occurs in the earth's crust on an average of a few parts per million; deposits as the mixed oxide U_3O_8 (Dana and Dana, 1944) occur in concentrations of about 0.1 to 1 percent (Eisenbud, 1973). The uranium ore is crushed and leached (usually with sulfuric acid for our low lime Canadian ores). Decanting and filtration yield a clear leach liquor, from which the uranium can then be precipitated with ammonia to give "yellowcake", with an approximate composition of $(NH_4)_2U_2O_7$.

Uranium-238, the predominant isotope in abundance and radioactivity in the ore, decays through a series of nuclear reactions to give eight alpha particles, six beta particles and numerous gamma rays, with a total energy emission of about $23 \times 10^9 \text{ J g}^{-1}$ of U^{238} ; the final end product is the stable nuclide lead 206. The decay products are in secular equilibrium with the uranium and thus they all have the same decay rates ($1.3 \times 10^4 \text{ Bq g}^{-1}U$). Typically, more than 99 percent of the radium-226 is removed by the initial separation at the mine site, so that the yellowcake received at the refinery may contain only a few Bq* of these nuclides per gram. This radium-226 which is rejected as refinery waste is, nevertheless, the prime source of

* Footnote - The SI unit of radioactivity is the becquerel (Bq) or one disintegration per second (dps). It equals 27 pCi.



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concern from a water quality standpoint. Until 1979, about 2.3×10^{13} Bq of radium had been disposed of at the site. Radium-226 decays by alpha and concomitant gamma decay (half-life 1600 years) to give the inert gas radon-222. This mobile daughter product also decays by alpha and gamma emission to give, ultimately, four alpha particles, four beta particles, several gamma rays, and finally, lead-206.

METHODS

The water samples were collected by pumping into one litre bottles. The radium was determined by allowing an equilibrium amount of radon-222 to grow in a concentrated sample, as described by Durham and Joshi (1980). The resulting alpha activity was then counted on a scintillation gas counter. The detection limit is about 1 mBq L^{-1} (one millibecquerel per litre).

The uranium was determined by exciting the uranyl ion in solution with a 377 nm pulsed nitrogen laser; the characteristic green fluorescent spectrum is measured photometrically and the detection limit of our instrument is $0.05 \mu\text{g L}^{-1}$ (Scintrex, 1978).

RESULTS TO 1980

In the 1980 report by Durham and Joshi, it was seen that the arsenic and nitrate in the water along the shoreline of the site were always less than the Ontario criterion for public water, hence these two pollutants were not determined during 1981-83.

The maximum radium-226 level for Ontario public waters is 110 m Bq L⁻¹ and this value was reached, or exceeded for only two of the samples reported on in 1980 (the values were 95 ± 2 mBq L⁻¹ and 270 ± 3 mBq L⁻¹ at locations marked C and D on Fig. 1. Over forty sampling piezometers have since been set up on the shore (Bobba et al., 1983), for the purpose of measuring groundwater levels and flows, and for taking groundwater samples; some of these allow for sampling at different depths. In 1982 twenty-six sites (identified by numbers from 0 to 25 in Fig. 1) were established. The earlier 1981 sites are identified by compound numbers: X/Y-Z. The X denotes the distance in metres east from the datum point 0/14. The Y denotes the distance in metres of the site from the shoreline. The Z, if present, denotes the depth below the terrain; otherwise, samples were taken from near the surface of the water table.

RESULTS FROM 1981

The radium and uranium concentrations found in the ground-water are given in Tables I to IV. The values appear in order of sampling sites from west to east, hence the mixed symbols in the headings. In order to simplify the presentation of results, no statistical counting errors are attached to the radium values, nor are uncertainties given for the uranium values. The standard deviations, σ , can, however, be estimated from the following table.

Radium-226 standard deviation (Tables I and II)

A (mBq L ⁻¹)	σ
1 - 10	0.11A
10 - 100	0.07A
100 - 1000	0.03A
1000	0.02A

Uranium standard deviation (Tables III and IV)

C (μg L ⁻¹)	σ
0.1 - 1000	0.15C

The raw data from which all the values in this report have been derived, along with their individual standard deviations, will be kept on file at NWRI and can be obtained from the senior author.

The radium-226 levels regularly exceed 110 mBq L^{-1} at seven locations (30/17, 3, S-1, 150, 177 and 180). In addition there was a single very high value of 6000 mBq L^{-1} in mid 1981, near the Eldorado east pond; this high concentration was not found again.

The uranium levels approach $1000 \text{ } \mu\text{g L}^{-1}$ at two sites (30/17 and 210); the Canadian drinking water standard specifies less than $20 \text{ } \mu\text{g L}^{-1}$. We will make simultaneous measurements of both the standpipe water and the lakewater during 1984 to ascertain the dilution between the two locations. It should be emphasized that although radioactivity on the site and in the underlying groundwater is hazardous, there is no reason to believe that this hazard extends for any significant distance into the lake.

A full report on the transport of toxic material and its impact on Lake Ontario will be prepared in about one year.

REFERENCES

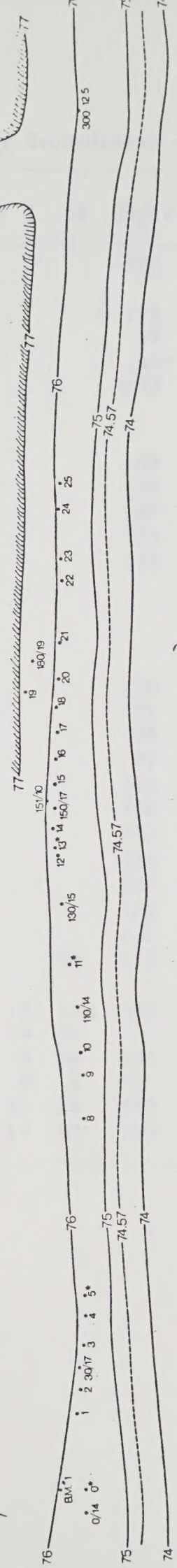
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Figure I. Port Granby Radioactive Waste Management Site (Located at about $43^{\circ}54'N$ $78^{\circ}27'W$. Station numbers are referred to in Tables I to IV.





Eldorado
Piezometer



0 10 20 metres

TABLE I. Port Granby Groundwater - West End Ra-226 (m Bq/L⁻¹)

Date	0/14	0	1	2	30/17	ELD 3	ELD 11	ELD 28	3	4	5
81-6-11	217				520						
81-6-16	16										
81-6-17	31				111	38					
81-6-23	28				97	132	7				
81-6-24	37				20			139			
81-6-25					203						
81-6-26											
81-6-30											
81-7-9	22				149						
81-7-22	19				173	91	51				
81-8-6	35				150	96	13	128			
81-8-26	20				174	67	10				
81-9-24	28				178		15				
81-11-17											
81-12-16											
82-4-27											
82-5-5	15				120						
82-5-13	17				151						
82-5-27	39				88						
82-6-10	41				77						
82-6-24	37				111						
82-7-8	30				156						
82-7-22	25				140						
82-8-5	51				154						
82-8-18	34				145						
82-9-2	68				126						
82-10-25	32				145						
82-11-18	37			26	123				108	67	41
83-1-6	28		17	11	125				149	45	
83-4-27	20		14	10					90		48
83-5-5	18	19	9	20	104				79	35	36
83-5-12	44	24	8	8	121				126	37	47
83-5-18	34	37	17	28	148				113	67	35
83-6-15	21	17	13	15	160				80	31	42

60/13	6	7	8	90/10	9	10	110 10	110 14-1	110 14-2	110 14-3	S-1	11	124/0	124/5	130 15
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1013

8

44
49
20
17
41
59

22 7 9 10 240 14

8
17
25

26
17
16
11
7
16
32

46	al	17	9	5	18
57	up	↑ 34	8	7	2
113	one space.	up 30	6	7	4
		one space	17	9	14
		32	10	1	5
		30	12	6	7
	Don't overp.	↓	17	4	14
			17	25	23
			12	5	7
		4	23	8 9	6 7

None
black
up one
space

359	34
687	107 18
993	597 12
844	431 63
1192	23
861	294 21
1173	534 54
658	303 20
931	379 30
741	539 266
612	428 38
566 ✓	321 31
481	330 26

24 25 10

18 28

18 13 22
8 5 8

17

16

17 11
15
12
18
8
16

18 12
14
8 6
7 10
4 6
7 16

6 8 9
6 4
15 158 4
8 8 4
46 46 4
26 26 11 8

412	8
764	989
1024	1402 39
1075	868 15
426	987 33
1171	638 18

Mar 8/89

TABLE II. Port Granby Groundwater - East End Ra-226 (m Bq/L⁻¹)

Date	12	13	14	150 10	150 17-1	150 17-2	150 17-3	150 TOP	150 BOT	15	16	17
81-6-11												
81-6-16												
81-6-17												
81-6-23												
81-6-24									25			
81-6-25				1784								
81-6-26												
81-6-30												
81-7-9				1556					897			
81-7-22				1482					369			
81-8-6				940				20	248			
81-8-26				1182				35	461			
81-9-24				969				34	558			
81-11-17				498				139	372			
81-12-16				291	24	8	13	34	337			
82-4-27				264	11	3	10					
82-5-5				399	15	5	8					
82-5-13				332	38	25	8					
82-5-27				270	20	6	32					
82-6-10				573		8	8					
82-6-24				712	177	26	11					
82-7-8				922	18	49	19					
82-7-22				718	22	66	14					
82-8-5				658	57	3	12					
82-8-18				591	31	11	27					
82-9-2				609	31	20	10					
82-10-25				404	46	13	14					
82-11-18	12	10	29	295	56	10	16			26	15	19 3
83-1-6	8			234	30	3	10			14	7	16
83-4-27	18	17				8	9			14	16	
83-5-5	22	8	10	335	60	7	13			19	13	13
83-5-12	16	12	12	428	15	10	10			19	7	7
83-5-18	10	15	11	176	23	13	18			22	28	7
83-6-15	22	17	7	429	31	17	11			22	10	9

19	20	177 5	180 10	180 19	21	22	23	210 11	24	25	235 11	270 6.5	ELDE	300 12.5	Lake One Sup.
			165	50											
								25			91	74	5994 ± 32	17	
		144	230					40			44	15	82	12	
		110	215					36			34	10	31	4	
			52					34			31	22	25	4	3
			81					36			40	22	35	7	4
			70					35			27	19	40	17	6
			69												
			85												
		325		12				21			18	18		2	
		528		131				24			14	17		4	
		725		1570				32			20	46		8	
			601					36			17	27			
		739		412				44			36	33		11	
		1056		298				42			26	30		7	
		1486		175				34			18	30		6	
		1114		100				53			26	21		11	
		1490		62				65			20	22		14	
		921		71				41			15	25		6	
		959		36				27			17	37		6	
6	31	647		33	62	228	51	33	45	29	14	24		14	
	44	753		31	33	30	44	21	16	8	11	17		5	
		512					40			12				3	
	14	323		638	51	70	43		11	17				10	
	19	453		168	38	48	47		8	20				11	
	11	594		67	27	58	54		7	17				8	
	18	336		38	15	48	36		9	16				6	

all correct

TABLE III. Port Granby Groundwater - West End Natural Uranium ($\mu\text{g/L}^{-1}$)

Date	0/14	0	1	2	30/17	3	4	5	60/13	6	7	8
82-4-27												
82-5-13	10.6				810				0.8			
82-5-27	11.7				864				17.8			
82-6-10	13.5				851				0.6			
82-6-24	14.4				780				2.2			
82-7-8	15.6				683				2.8			
82-7-22	13.3				789				1.5			
82-8-5	18.3				794				1.1			
82-8-18	22				800				1.1			
82-9-2	12.5				833				0.7			
82-10-25	9.6				868				0.6			
82-11-18	13.6			863	812	167	66	23	1.0	1.7	1.9	2.3
83-1-6	15.8		47	823	876	181	68		2.9		2.3	0.9
83-4-27	11.5		75	786		213		28				3.7
83-5-5	9.8	606	115	942	988	226	156	25				1.3
83-5-12	11.7	598	98	699	822	225	200	30				1.5
83-5-18	10.5	579	81	718	894	216	194	21				1.0
83-6-15												

TABLE IV. Port Granby Groundwater - East End Natural Uranium ($\mu\text{g/L}^{-1}$)

Date	12	13	14	150 10	150 17-1	150 17-2	150 17-3	15	16	17	18
82-4-27				5.6	2.7	0.6	0.1				
82-5-13				15.6	6.7	6.7	2.4				
82-5-27				15.0	0.8	0.7	0.6				
82-6-10				15.8	14.5	0.7	0.2				
82-6-24				29	15.8	4.1	0.8				
82-7-8						1.8	1.5				
82-7-22				30	3.8	2.9	1.5				
82-8-5				26	2.4	0.6	0.5				
82-8-18				18.2	4.8	1.5	0.3				
82-9-2				17.4	3.9	0.3	0.1				
82-10-25				17.4	14.4	1.3	0.2				
82-11-18	4.0	0.5	7.0	10.9	2.0	2.7	0.1	9.2	7.8	5.0	13.3
83-1-6	2.5			6.1	1.0	0.2	0.1	5.9	4.4	4.5	6.8
83-4-27	1.5	5.1				0.2	1.1	2.0	3.5		1.1
83-5-5	2.1	0.3	0.7	13.9	0.1	0.3	0.2	3.0	4.6	2.3	3.1
83-5-12	1.7	0.3	0.3	16.5	0.7	0.3	0	2.2	2.5	5.9	2.0
83-5-18	1.5	0.2	1.4	16.4	0.5	0.7	0.2	2.2	4.0	3.1	2.9

90	9	10	110 10	110 14-1	110 14-2	110 14-3	11	124/0	124/5	130 15
9.1			0.4	0.3	0.2	0.6		42		3.3
12.9			2.0	0.4	0.6	0.5		34	28	3.9
			4.0	0.6	1.1	0.8		38	22	20
				0.3	0.2	0.3		22		3.3
			8.1	0.3	0.2	1.9		23	21	4.6
				3.2	0.2	9.5				
			3.2	1.5	2.0	0.8		32	23	2.7
				0.3	0.2	2.6		0.5	19	12.7
				0.6	2.6	0.6		25	21	9.5
				0.4	1.2	0.2		30	26	5.6
				0.3	0.4	0		32	32	2.8
	3.3	2.7		0.6	0.2	0.2	2.0	40	49	1.8
	2.0	2.0		0.2	0.1	0.2		43	15	1.9
	2.2				0.4	0.4	1.8	76	56	
	2.9	2.3		0.2	0.3	0.2	0.4	86	56	3.9
	1.8	2.4		0.2	0.2	0.3	0.7	59	53	4.8
	1.8	2.2		0.3	0.3	0.2	0.8	66	48	3.6

9	20	177 5	180 19	21	22	23	210 11	24	25	235 11	270 6.5	300 12.5
		204	169				613			24	1.8	0.6
		125	216				685			26	0.9	35
			233				833			40	0.8	0.8
		131	124				892			15.4	0.4	2.4
		110	76				756			3.8	1.2	0.6
		150	110				420			103	1.5	10.3
		40	143				716			19.4	1.1	0.4
		96	125				909			25	1.0	0.9
		106	122				625			17.8	1.0	15.3
		154	167				833			175	0.4	0.8
4	20	210	159	60	96	491	833	150	129	15.9	0.8	0.5
	15.5	177	162	52	121	425	810	292	38	15.4	2.6	0.4
		146				703			53			0.9
	9.1	95	400	77	120	706		45	10.8			0.7
	6.9	112	192	74	141	655		45	10.0			0.9
	11.1	86	166	82	158	727		47				

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